A goal-directed rational component for emotional agents

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ABSTRACT

This paper presents a goal-directed rational component of an emotional agent. A main feature of the proposed model of rational component concerns its interaction between rationality, personality and emotions, mainly in the goal selection and action selection processes and in the rational state evolution. Such evolution takes place in two ways: implicitly, the behavior of the rational component changes according to the current emotional state; explicitly, the emotional knowledge is encoded as facts in the working memory of a production system. The paper describes each component of the rational module, its mechanisms, its inputs and its outputs and how the interactions with emotions and personality are realized.

Our research aims are directed toward applications of emotional agents to multimodal environments, with particular interest to intelligent interaction and communication by means of music, dance, movements of robots, visual media and in general applications where non-verbal communication mechanisms are the main communication channels between human and machines. Such requirements guided us in the definition of the model presented in this paper.

1. INTRODUCTION

In a general architecture for emotional agents, the main task of the rational component is to hold and update the rational state of the agent. Furthermore, a believable agent [5] has to exhibit a goal-directed behavior: therefore, the rational component has also to choose the current goals of the agent and the actions to accomplish them.

AI researchers developed several models and techniques to realize agents with a rational behavior, but in applications such as interactive entertainment, tools for teaching by playing or guides in a museum or exhibit, where the expression of emotional and affect contents is of paramount importance in order to achieve a natural and effective human-computer interaction, we have to concentrate our efforts on the interaction between rationality and emotion. In particular, the mechanisms of goal selection and action selection of an emotional agent must reflect its expressive intentions.

In this paper we present an architecture for the rational component of an emotional agent. In particular, the proposed rational component can be embedded within a general architecture for emotional agents that contain both deliberative and reactive processes [2].

The component is conceived to work in application domains where the main interest is in non-verbal communication. In particular, we utilize it in multimodal environment where music, dance, movements of robots, and visual media are the main channels of interaction between human and machines.

In Section 2 we present the interaction between rationality and emotions we developed in our architecture. In Section 3 we describe the rational module and its components. In Section 4 we draw some conclusions and sketch future developments.

2. INTERACTION BETWEEN RATIONALITY AND EMOTIONS

Figure 1 shows the main interactions between a goal-directed rational component and an emotional component in an emotional agent.

![Figure 1: Interaction between rationality and emotions](image)

In order to express emotional content, the agent holds an emotional state influencing the work of a goal-directed rational component in several ways. The architecture we propose takes into account the three following types:

- The direct dependence of the rational evolving knowledge on the current emotional state: in this way we obtain an agent which evaluates situations and consequences of its actions in dependence on its current emotions.
- The mechanism of action selection on the basis of the current rational and emotional states. The agent must select an action to satisfy its goals. The selected action has to reflect the agent’s mood: for instance, if the previous goals succeeded, the agent might acquire courage and its actions should result more determined and resolute.
- The mechanism of goal selection not only on the basis of the rational and emotional states but also on the basis of the agent’s personality. For instance, an ambitious agent might choose more difficult goals than a fearful one and an agent that successfully satisfied its previous goals could choose some more ambitious ones.

We consider also the influence of the current rational state on the evolution of the emotional state. In particular success and failures of goals produce positive and negative stimuli, which modify the emotional state of the agent. The intensity should be proportional to the importance of the goal or action which caused the generation of stimuli.
3. THE RATIONAL COMPONENT ARCHITECTURE

The overall structure of the rational component is shown in Figure 2.

The five rectangles represent active modules:

- A data driven production system
- A goal management component
- An action selection component
- A rational input component
- A rational output component

The arrows represent information flows between the modules. They are implemented as buffers upon which the first component acts as a producer and the second as a consumer. Available goals are stored in a goal memory. In the remainder of this section we describe each component in more detail.

The rational input component

The rational input component gathers information coming from the other components of the general architecture: in particular, it processes inputs from the input component of the general architecture (see [2] for more details on the general architecture). The main task of the rational input component is to extract from incoming input data environmental information and "kansei" information.

"Kansei" is a Japanese word to express concepts like "sense", "sensuality", "emotion", "feeling" in the sense of acquired sensibility towards art and music as a whole [3]. Thus, when we say "kansei" information, we mean information related to emotions and personality in some way. For instance, if the current emotional state is represented by a position in a multidimensional emotional space, such a position is certainly part of what we call "kansei" information.

The generation of environmental information depends on perceptions coming from the input component of the general architecture [2]. Therefore, the environmental information is related to situations that characterize the environment the agent operates in. For instance, information about what happens in the external world is part of what we call environmental information.

"Kansei" information and environmental information are sent to the other components in the required format: for instance, on the basis of such information new facts could be asserted in the working memory of the production system or old facts could be retracted producing an evolution in the rational state. The goal manager and the action selector update also their parameters depending on the information they receive from the rational input component.

The rational output component

The rational output component sends information to the other components of the general architecture in order to execute the action selected by the rational component. It also notifies the other components and in particular the emotional component of the success or failure of the current active goal.

The goal management component

The goal management component selects and manages the goals of the agent.

The current active goal is chosen on the basis of environmental information coming from the external world and on the basis of "kansei" information related to the emotions and personality that the agent want to express. Such information comes from the rational input component.

The goal manager selects the current active goal from a list of goals. The author of the application provides the initial goal list. New goals can be added at runtime as a consequence of the interactions between the agent and the world. The generation of new goals could be committed to some learning algorithm. New goals could also come from other components of the general architecture: in particular, the emotional component could produce stimuli in the rational component causing new goals, thus directly arising from the emotional contents. In consequence of its choice the goal management component returns the selected goal as output.

The goal management component manages the current goal of the agent and the goals contained in the goal list by updating some data associated to such goals on the basis of information coming from the rational input component. In particular, it has to verify if the current active goal succeeds or fails. If the current active goal is still active, the goal management component verifies if its priority is still sufficiently high. If such priority is lower than an established threshold, the current active goal fails partially.

An example of goal management component

A realization of the goal management component is shown in Figure 3.

The component is divided into two main parts: an information processing module and a decision making module. The information processing module manages the current active goals.
and the goal list, while the decision maker contains a goal selection algorithm.
In particular, we implemented a decision maker utilizing a multiattribute decision making algorithm: in this case, the goals are the alternatives among which the algorithm makes its decision.
We need also to define a set of attributes: their values should be generated depending on “kansel” information and environmental information. In this way the goal manager builds and updates a decision table that is the input of the decision making algorithm. Information about the last selected goal is maintained in order to avoid the continuous selection of the same goal.
Some attributes could be related to the environmental side, others to the emotional side. In addition, the algorithm calculating the values of the attributes as well as the decision making algorithm may contain parameters directly dependent on the current emotional state and on the agent personality. Thus, emotions and personality take part in the goal selection processes in several ways giving an effective interaction between emotion and reason.

An example of goal selection algorithm
As we said above, we propose a decision maker utilizing a multiattribute decision making algorithm: in this section we present a possible set of attributes and an algorithm to make the decision.
Three simple attributes we are utilizing are as follows:
• Priority: it’s a measure of the suitability of a goal with respect to the external world.
• Importance: in this case is not synonymous of priority: in fact, it is a measure of the suitability of a goal with respect to the agent’s personality, feelings and emotions.
• Easiness: it’s a measure of the feasibility of a goal.
The initial value of each attribute is assigned by the author of the application. Then, the values can be updated at runtime by the information processing module.
Here below, we show the decision table, when we consider only the three previous attributes. Other attributes can be added to improve the decision making process.

<table>
<thead>
<tr>
<th>Goals</th>
<th>Priority</th>
<th>Importance</th>
<th>Easiness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goal 1</td>
<td>x11</td>
<td>x12</td>
<td>x14</td>
</tr>
<tr>
<td>Goal 2</td>
<td>x21</td>
<td>x22</td>
<td>x24</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Goal i</td>
<td>xxi</td>
<td>xxi</td>
<td>xxi</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Goal n</td>
<td>xni</td>
<td>xni</td>
<td>xni</td>
</tr>
</tbody>
</table>

A decision making algorithm we are testing is a simple variation of the classical Hurwicz’s multiattribute method. In particular, we are using the following algorithm:

“Between the goals having the priority value \( x_{ij} \geq x_0 \) (\( x_0 \) threshold), the set of the selected goals is \( A^* \) such that:

\[
A^* = \{ A : i = \arg \max_1 [\alpha \min_m z_i + (1-\alpha) \max_m z_i] \} \quad \alpha \in [0,1]
\]

with \( z_{ij} = w_j x_{ij} \) and \( w_j \) weights such that

\[
\sum w_j = 1
\]

If this case the decision parameters are \( \alpha \) and the weights \( w_j \). They can be calculated by the information processor depending on “kansel” information. The value of \( \alpha \) could be interpreted as a measure of the agent’s “pessimism”. In fact, if \( \alpha \rightarrow 1 \), the agent should tend to pay greater attention to the minimum value of the attributes, whereas if \( \alpha \rightarrow 0 \), the agent should consider mainly the maximum value of the attributes. The weights \( w_j \) reflect in some way the agent’s personality, too. For instance, an ambitious agent should have the importance weight greater than the easiness weight. The weights \( w_j \) and the parameter \( \alpha \) could be the output of some learning algorithm that calculates them depending on the agent’s experiences during its interactions with the world, the humans and other agents.

The action selection component
The action selection component chooses the action to execute between the actions received by the production system. The actions that the production system sends to the action selector can be considered rationally equivalent: so, the action selector makes its decision principally on the basis of the current emotional state. In fact, from a certain point of view, the behavior of the action selector is quite similar to the behavior of the goal manager, but we have to consider that the decisions made by the goal manager are at a higher level than the decisions made by the action selector: the goal manager selects between several long term goals, while the action selector chooses an action that should be applied in a particular and limited situation.
The action selector can be realized like the decision maker module of the goal manager, but there are also some other different ways to implement it. For instance, if we represent emotions in a multidimensional emotional space, we can characterize the emotional content of an action by placing it in the emotional space. In this way, several different actions will be represented by several different points in the emotional space. Action points might be dynamically assigned in the emotional space. The emotional state the agent want to express will be also a point in the emotional space. The actions that are neutral with respect to emotions can be placed in the origin of the emotional space. Now, if we want an easy method to make a decision, we can select simply the nearest action with respect to the emotional state the agent want to express.
The action selection component receives only “kansel” information from the rational input component. In fact, it utilizes only “kansel” information to make its choice. On the other hand, the production system selects the rationally equivalent and applicable actions only on the basis of environmental information.

The production system
The production system holds and updates the rational state and utilizes it to select the actions in order to pursue the current active goal. The production system could also help the goal management component when it has to verify if the current goal succeeded or failed. In fact, such tests could be implemented by some success and failure rules within the production system.
In general the author of the application has to define four rule sets:

• A set of rules for the evolution of the rational state.
• A set of rules to verify the state of the current goal, if the goal management component utilizes them. Generally there will be a success test and a failure test for each goal.
• A set of rules to determine what actions are applicable in the current situation. The production system sends the applicable actions to the action selector component that chooses one of them. Generally there will be a subset of such rules for each goal.

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A set of rules to verify if the action chosen by the action selector is immediately executable. In fact, if the selected action is too complex, it can be decomposed into subgoals with a top down method. After that, the rational component repeats the action selection process until the action selector chooses an executable action: that action is sent to the rational output component that generates the instructions to execute it.

Rational component at work
The activity of the rational component can be described as follows:
1. The rational input component processes information from the input component of the general architecture and the emotional-rational parameter, and produces "kansai" information, environmental information and facts to assert or retract in the working memory of the production system.
2. The goal management component and the action selection component receive "kansai" information and environmental information and update their parameters.
3. The production system activates the set of rules for the evolution of the rational state and calculates a new rational state.
4. The goal management component, possibly supported by the production system, verifies if the current goal succeeded or failed. If the current active goal is still active, the goal management component verifies if its priority is still sufficiently high. When the goal manager detects a success, a failure or a partial failure, it selects a new goal and the rational output component generates information and emotional stimuli that are sent to the other components of the general architecture.
5. The production system activates the set of rules to determine what actions are applicable and rationally equivalent in the current situation with the current goal or subgoal.
6. The action selection component chooses the action to execute.
7. The production system verifies if the action the action selector chose is immediately executable.
8. If the selected action is immediately executable, the rational output component receives instructions that are sent to the other components of the general architecture. If the action is not immediately executable, the production system determines, with a top down method, subgoals to satisfy in order to accomplish the complex action and comes back to 5. The subgoals can be memorized in a stack: when a subgoal succeeds, it is removed from the stack and the production system considers the next subgoal; when it fails, the complex action fails and the rational component removes all the subgoals related to the failed complex action.

4. CONCLUSIONS AND FUTURE WORK
A main goal of the proposed architecture is to experiment the interaction between rationality, personality and emotions in the framework of emotional agents in the application domain discussed in the paper.
In particular, the rational component supports a rational state evolving on the basis of both rational and emotional knowledge. Such evolution takes place in two ways: implicitly, the decision parameters are updated depending on the current emotional state; explicitly, the emotional knowledge is encoded as facts in the production system working memory. The model supports also a rational choice of a set of possible actions and an emotional and personality based selection of the current goal and action. The rational component has been implemented and is under testing in several concrete applications: tools for teaching by playing and experiencing in simulated environments, cultural and museum applications that involve autonomous robots that act as guides or special visitors to attract, entertain and instruct visitors.
Given our main interest is in the concrete realization and experimentation of the basic interactions between rationality, behavior, personality and emotion in the fields of application described above, our model has currently some limitations from the point of view of rational processing.
Here follow some directions of our future research. Our current prototype of rational component can manage a single active goal at the same time: in applications containing complex real-time human-machine interaction, there might emerge the need of several active goals at the same time.
Action management can be enhanced, too. In particular, the success or failure of immediately executable actions is not explicitly considered in the current prototype. However, we are embedding the action selection component into a more complex action management component able to evaluate the result of the current action as the goal management component does with the goals.
We are also investigating other methods for action and goal selection, also related to learning capabilities. In particular, emotional agents should be able to adapt existing and learn new goals and actions from their experience. The goal and action selection parameters should also be updated depending on agent's experience.
Finally, we have to remark that the production system is not a planner, therefore there is no planning in our architecture. It could be interesting to introduce a planner to pursue the goals leaving to the production system only the rational knowledge evolution.
These new features will be introduced gradually in the architecture, basically driven by the experiments, real needs and results derived from the use of the prototype system at work in the concrete applications described in the paper.

5. REFERENCES